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A Precocious Appetite: Industrial Agriculture and the Fertiliser Revolution in Java's Colonial Cane Fields, *c.* 1880–1914

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Late colonial sugar cane production in Java was characterised by the heavy use of (chemical) fertiliser in tandem with labour-intensive techniques and industrial work processes in the field. This article provides a useful corrective to an overemphasis on the extractive nature of the colonial economy of sugar and shows the truly industrial nature of plantation production. For students of colonial science and agriculture, the situation has additional ramifications, relating both to the role and 'diffusion' of scientific knowledge and to the historical dimensions of agricultural development in 'the tropics'.

A few years before the outbreak of the First World War, the newly established International Institute for Agriculture in Rome (the precursor of the present-day Food and Agriculture Organisation of the United Nations) began collecting data on the worldwide production and use of chemical fertilisers. Its findings still have the power to astonish. They reveal that the Indonesian island of Java, with an area of no more than 125,500 square kilometres, considerable tracts of which are volcanic slopes inhospitable to most forms of agriculture, was nonetheless the seventh largest international consumer of sulphate of ammonia.[1] The great bulk of this nitrogenous fertiliser was consumed in

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1 On the international production of, and trade in, sulphate of ammonia from 1907 to 1916, see *Annuaire international de statistique agricole, 1915 et 1916* (Rome: Imprimerie de l' Institut International d'Agriculture, 1917), pp. 790–1, 822–3. In the case of the Netherlands Indies (Java), the Rome Institute's data needs to be supplemented by that relating to imports of sulphate of ammonia contained in *Statistiek van den handel en de in- en uitvoerechten in Nederlands-Indië over het jaar . . . samengesteld bij het hoofdbureau der in- en uitvoerrechten* (Batavia, Landsdrukkerij, 1909). For contemporary discussion of this evidence and its relation to Java, see: 'Wereldproductie en wereld verbruik van kunstmestoffen', *Archief voor de Suikerindustrie in Nederlandsch Indie* (hereafter *Archief Suiker*), 21, 2 (1913): 1430–2; C. J. Milo, 'Het luchtstikstofmeststoffen, hare bereiding en het belang voor de Java suikerindustrie', *Archief Suiker*, 19, 2 (1911): 1053–75, 1093–134; and W. J. v. d. Leemkolk, 'Gebrek aan meststoffen', *Tijdschrift voor Nijverheid en Landbouw in Nederlandsch Indie*, 91 (1915): 99–113.

the West, where its main producers were almost exclusively located. In this context, Java's consumption of some 68,000 metric tons, or around one-twentieth of the world's total, was phenomenal in global terms. Indeed, outside the West only Japan (115,000 metric tons) had a higher recorded consumption than Java.[2] This article sets out to explain the extent of this consumption, and to locate it in developments in agricultural commodity production that took place on the island at the very end of the nineteenth century. In so doing, it sets out to describe and analyse a form of industrial agriculture that needs to be understood as a significant manifestation of economic modernity in a tropical setting.

The topic is an important one, and not only for intrinsic reasons. What I shall term the 'fertiliser revolution' in Java's late colonial sugar industry, and the larger framework of industrial agriculture in the cane field in which it was embedded, has implications for an on-going debate about the 'fecundity' of the tropics and the extent to which climatic and ecological conditions in tropical regions form a critical obstacle to agricultural development. Although this debate is essentially subordinate to the overall thrust of the present study – which is toward a better understanding of the dynamics of the agricultural sector of late colonial sugar production in Dutch Java – it is nonetheless an important underlying theme to the discussion that follows.

The agricultural potential of 'the tropics' *vis-à-vis* those of temperate and sub-tropical zones has been the subject of considerable attention in recent decades among scholars concerned with explaining underdevelopment in terms other than those assumed in arguments about the 'malignancy' of the imperial connection (or, alternatively, the 'laziness of the native'). In so far as there is an established orthodoxy in this field of research, it has tended toward the conclusion that tropical agriculture is more heavily influenced – for the worse – by ecological and climatic factors than was once recognised.[3] In contrast to the ancient myth of 'tropical fecundity',[4] it has emphasised (*inter alia*) that the apparent luxuriance of plant growth, on which that myth was largely based, conceals a wide variety of fundamental ecological constraints to agricultural development. Indeed, there is a widespread contention that 'tropical countries have lagged during the last two hundred years in the process of modern economic growth', and that soil types and weather patterns have a great deal to do with this.[5]

2 Total recorded world consumption in 1913 amounted to 1,286,757 metric tons. Germany accounted for nearly 36 per cent (460,000), the United States for nearly 21 per cent (266,850) and France for 7.5 per cent (97,000). Elsewhere in the 'Third World', Egypt accounted for a very modest 1,650 tons and the Indian Ocean island of Mauritius was importing 5,000 tons annually by 1913. See Leemkolk, 'Gebrek van meststoffen', p. 111; and *Statistique agricole* 1917, p. 829.

3 Jeffrey D. Sachs, 'Tropical underdevelopment', *CID working paper no. 57* (Cambridge, MA: Harvard University Centre for International Development, 2000); Stanley L. Engerman and Kenneth L. Sokoloff, 'Factor endowments, institutions, and differential paths of growth among New World economies: A view from economic historians of the United States', in *How Latin America fell behind*, ed. Stephen Haber (Stanford: Stanford University Press, 1997), pp. 260–304.

4 Peter Boomgaard, 'From rice to riches? Rice production and trade in (Southeast) Asia, particularly Indonesia, 1500–1950', paper written for the workshop on 'The wealth of nature: How natural resources have shaped Asian history, 1600–2000', NIAS, Wassenaar, The Netherlands, 24–25 May 2004, p. 2. I am grateful to Professor Boomgaard for having kindly made available to me a copy of this paper, prior to its publication. On the myth of 'tropical exuberance' in general, see Philip D. Curtin, *The image of Africa: British ideas and action, 1780–1850* (Madison: University of Wisconsin Press, 1964), p. 60.

5 Andrew M. Kamarck, *The tropics and economic development* (Baltimore and London: The Johns Hopkins University Press), p. 10.

In a sense, the case of Java is tangential to such debates, in so far as they concentrate on the 'humid tropics' (in which rainfall is more or less constant), rather than on the 'wet-and-dry' or monsoonal regions to which most of lowland Java better equates. Java also departs from the tropical 'norm' in respect to the relative fertility of its volcanic soils.[6] Nonetheless, in a broad sense Java remains firmly within the category concerned, albeit with significant atypical characteristics. In consequence, the extent of the colonial achievement there in terms of the highly productive, industrial-style agriculture of sugar cane should give cause for thought: it appears to be an awkward fit with some aspects of general theories about the limitations imposed by soil and climate on agricultural development in tropical regions. (It should be pointed out that most of the world's main cane sugar industries were in *sub*-tropical regions.) At the very least, the history of Java's colonial cane fields at the close of the nineteenth century undermines any overly determined assumption that agricultural conditions in the tropics invariably placed major obstacles in the way of the kind of developments that took place in other, more temperate regions.

A precocious appetite

Java's precocious appetite for chemicals was accounted for almost entirely by the island's colonial sugar industry, by then the second largest producer-exporter of cane sugar in the world. It was an appetite that has been largely ignored, however, in recent research literature,[7] despite its potential for radically altering our understanding of the dynamics of this particular branch of commodity agriculture. Indeed, for all that there exists an extensive colonial-era literature on the subject, the role played by fertiliser in securing productivity has been largely neglected in recent decades.

Of course, the sheer fertility of Java's cane fields and the regular, bumper crops that the industry obtained from them have not escaped the attention of historians. Few have attempted to explain it, however, other than in terms of the application of 'limitless' amounts of labour to the colony's 'best' farmland. Within this context, in so far as there is a single, hegemonic explanation of the internationally exceptionally high yields in the agricultural sector of the Java industry, it is focused on *wisselbouw*, an elaborate system of crop rotation devised for sugar and 'peasant' crops associated with the *Cultuurstelsel* or System of [State] Cultivation, under whose aegis the industry had been re-launched in the middle decades of the nineteenth century.[8] This reading found its most influential

6 Jen-Hu Chang, 'The agricultural potential of the humid tropics', *The Geographical Review*, 58, 3 (1968): 333–61; Wolfgang Weischet and Cesar N. Caviedes, *The persisting ecological constraints of tropical agriculture* (Harlow: Longman Scientific and Technical, 1993), pp. 3–6, 160–6; Sachs, 'Tropical underdevelopement', pp. 4–7; Kamarck, *The tropics*, pp. 3–28.

7 Peter Boomgaard, 'Treacherous cane: the Java sugar industry', in *The world sugar economy in war and depression*, ed. Bill Albert and Adrian Graves (London: Routledge, 1988), pp. 157–69; Robert E. Elson, *Javanese peasants and the colonial sugar industry: Impact and change in an East Java residency, 1830–1940* (Singapore: Oxford University Press, 1984); M. R. Fernando, 'Peasants and plantation economy: The social impact of the European plantation economy in Cirebon residency from the Cultivation System to the end of the first decade of the twentieth century' (Ph.D. diss., Monash University, 1982); G. Roger Knight, *Colonial production in provincial Java: The sugar industry in Pekalongan-Tegal, 1800–1942* (Amsterdam: V.U. Press, 1993); Djoko Suryo, 'Social and economic life in rural Semarang under colonial rule in the later nineteenth century' (Ph.D. diss., Monash University, 1982).

8 An early subscriber to the notion was W. L. de Sturler, whose *Handboek voor de landbouw in Nederlandsch Oost-Indie*, was published in Leiden by Sythoff in 1863.

advocate, albeit almost by happenstance, in the work of the mid-twentieth-century cultural anthropologist Clifford Geertz, who argued that cane depended for its success on the degree to which it was symbiotically embedded in the cycle of peasant agriculture. Although his argument was directed primarily at the impact of this symbiosis on the socio-economy of Java's peasantry, it carried the strong implication that sugar cane became part of a self-contained and fundamentally self-replenishing agricultural cycle, dependent on nature's bounty, in which the needs of both cane and rice were met by inundation with sediment-rich water from Java's volcanic uplands.[9]

Reality was different. By the late nineteenth century, cane cultivation in Java was far from self-sustaining in the agricultural sense: land that had been intensively under cane since the inauguration of the *Cultuurstelsel* in the mid-nineteenth century was increasingly reported as '*rietmoed*', a contemporary term literally meaning 'cane-weary'.[10] Partly to counter this, from the 1880s onward, huge amounts of fertiliser were expended on Java's cane fields, meaning that the island's colonial industry participated, at a regionally precocious date, in what has been identified as the 'second' agricultural revolution. Conventionally, at least, the first agricultural revolution was associated with the rotation of crops and radical changes in animal husbandry. This second revolution, usually dated in western Europe and North America from the mid-nineteenth century, saw the transformation of agriculture into a manufacturing industry in its own right. Commercially manufactured inputs, principally of fertiliser and feedstuffs, came to play an essential role in securing what itself became a manufactured output. To adopt the phraseology of F. M. Thompson's classic account of shifts in agriculture in the West, colonial cane farming in Java 'became an activity in which, at least in a significant degree, purchased raw materials are processed in order to produce a saleable finished product'.[11] These developments took place before, and largely independent of, the extensive mechanisation of agriculture, something that had scarcely begun when the nineteenth century ended. The absence of mechanisation in the cane field did not mean, however, that cane agriculture in late colonial Java was and remained essentially 'pre-industrial' in character: indeed, quite the opposite was the case.

Comparatively low labour costs enabled the industry to invest lavishly in fertiliser, because it could afford to do so without forcing up plantation costs to unsustainable levels. However, it is also fully apparent that the industry's achievements in the field – and the international comparative advantage derived from them – stemmed from the extent to which sugar plantation agriculture in Java, articulated through the fertiliser revolution, became both labour-intensive and industrialised at the same time, countering any assumption that the two were polar opposites. Quite explicitly, the case of Java sugar

9 Clifford Geertz, *Agricultural involution: The process of ecological change in Java* (Berkeley: California University Press, 1963).

10 H. Obertop, 'Verslag omtrent een inspectie besoek aan de suikerondernemingen van de cultuurmij. Wonolangan, 16.12.1901', in Dossiers Cultuurs: Wonolangan, Archief Nationaal, The Hague (hereafter NA), Archief Nederlandsch Handelsmaatschappij (hereafter NHM), 7950.

11 F. M. L. Thompson, 'The second agricultural revolution, 1815–1880', *Economic History Review*, 2nd series, 21 (1968): 62–77; Thompson, 'Agriculture and economic growth in Britain', in *The nature of industrialisation. Vol. 4, Agriculture and industrialisation: From the eighteenth century to the present day*, ed. Peter Matthias and John A. Davis (Oxford: Blackwell, 1996), pp. 40–68; Thompson, 'Agricultural, chemical and fertiliser industries', in *The agrarian history of England and Wales*, ed. E. J. T. Collins (Cambridge: Cambridge University Press, 2000), pp. 1019–44.

serves to confound the notion, widely associated with the work of Arthur Lewis, that in tropical conditions 'cheap' labour had an inhibiting effect on technological progress in agriculture.[12] In the case of Java, the concept only holds true if that progress is measured simply in terms of the machine. In fact, the advance of industrial agriculture needs to be conceived in much broader terms. The relative availability and cheapness of labour, rather than being an end in itself, was made into the basis for a radically transformed agriculture of cane, heavily dependent on industrial inputs and characterised by commensurate industrial work routines. The effect is to locate the agricultural sector of Java's late colonial sugar industry on what has been posited as a characteristically 'East Asian' labour-intensive path to industrialisation rather than the purportedly 'Western' capital-intensive one.[13] Within an overall context where land was scarce and labour plentiful, moreover, fertiliser acted as a land substitute. Technical progress took the form not of mechanisation but of 'land-saving' through the intensified application of labour and other closely associated forms of inputs.[14] During the period under consideration, fertiliser was the most prominent of these, but the list also included highly specialised cane propagation, pest control, irrigation and increasingly meticulous land preparation.

What is also at stake in the history of the fertiliser revolution in Java's cane fields, of course (though it is only a minor theme of the present argument) is the residual notion of a simple diffusion from 'the West' in respect to the nexus between (field) science and colonialism.[15] The antecedents of the Fertiliser Revolution were to be found in long-standing practice in Java itself, as well as in exogenous science, and to an extent that reflects a gathering critique of diffusion. The case of Java sugar underlines both the value of 'expatriate' European expertise and the importance of indigenous, local foundations on which it could build, and within whose parameters it could hope to flourish. To adopt Stuart McCook's evocative phrase, it was 'a creole science' whose ambiguous location transcended sharp distinctions between colony and metropolis.[16]

The origins and course of the Fertiliser Revolution

Java's colonial sugar producers were fortunate that the coming of age of the modern chemical fertiliser industry largely coincided with the period in which they most had need of it. Industrial fertilisers began to be a significant force in agriculture in western Europe and the United States from around the mid-nineteenth century.[17] Initially, many

12 Arthur W. Lewis, *Growth and fluctuations, 1870–1913* (London: Allen and Unwin, 1978). For a critical engagement with Lewis's argument in a New World context, see Alan Dye, *Cuban sugar in the age of mass production* (Stanford: Stanford University Press, 1998), pp. 69–70; and Cesar J. Ayala, *American sugar kingdom: The plantation economy of the Spanish Caribbean, 1898–1934* (Chapel Hill: University of North Carolina Press, 1999), pp. 2–3 and 10–15.

13 Kaoru Sugihara, 'Agriculture and industrialisation. The Japanese experience', in *Agriculture and industrialisation*, ed. Mathias and Davis, pp. 151–2.

14 Yujiro Hayami, *A century of agricultural growth in Japan: Its relevance to Asian development* (Minneapolis: University of Minnesota Press, 1975).

15 William Kelleher Storey, *Science and power in colonial Mauritius* (Rochester, NY: University of Rochester Press, 1997), pp. 1–3.

16 Stuart McCook, *States of nature: Science, agriculture and the environment in the Spanish Caribbean, 1760–1940* (Austin: University of Texas Press, 2002), pp. 4–6.

17 Richard A. Wines, *Fertiliser in America* (Philadelphia: Temple University Press 1985), pp. 142–61.

fertilisers were of dubious quality and of doubtful efficacy. From the 1870s onward, however, and in tandem with falls in international freight rates, consistent, reputable chemical fertilisers with a predominantly phosphate or nitrogen base began to be developed by major producers in the West, with an eye not only to their own but also to specifically colonial markets. Characteristically, a pamphlet of the 1890s advertising 'Cross's Celebrated Fertilisers' – the firm's Port Dundas works in Glasgow was claimed to be 'among the most extensive in the world' – made specific reference to their products for 'Sugarcane, Tobacco, Coffee etc.' and their widespread 'Agencies in the Colonies'.[18]

Sulphate of ammonia itself – or ZA to use its standard Dutch acronym – was a rather special case. Originally a by-product of the gas works and coke-ovens of the industrialised world, sulphate of ammonia subsequently began to be directly manufactured, eventually on a massive scale, by industrial methods (based on the Haber-Bosch process developed early in the twentieth century) that were first applied commercially in Germany on the eve of the First World War.[19] In the 1880s, however, sulphate of ammonia had become the fertiliser of choice for the sugar beet farmers of Germany.[20] The agricultural experts who were employed in the Java sugar industry from the 1880s onward certainly were fully conversant with the German beet industry in particular; indeed, many of them had received their training there.[21] Nonetheless, an appreciation of the advantages of sulphate of ammonia for cane cultivation resulted from nearly a decade of experimentation in Java itself, and only after the more conventional phosphate and potash-based fertilisers had failed to answer to the particular requirements of *sawah*-grown cane.

In the beginning the Fertiliser Revolution in Java owed relatively little to chemical, industrially manufactured and imported fertilisers in any shape or form. Instead, it got under way with organic, locally available fertiliser in the form of what the Javanese called *bungkil* or oil cake, generally comprised of the residue of *kacang* (nuts) that had been crushed for their oil.[22] Manufactures of *bungkil* were predominantly members of Java's locally settled and largely acculturated 'Chinese' communities, the people, that is to say, who had been largely in charge of sugar production in Java since the seventeenth century, and who were only partially sidelined by mid-nineteenth-century developments.[23] There is further, though somewhat fragmentary evidence of *bungkil*'s use during the era of the *Cultuurstelsel* between 1830 and its dismantlement in the 1870s and 1880s.[24] At the

18 See enclosure in (the Rotterdam firm) A. J. van Breen (Cross's exclusive agents in Holland) to the NHM 30.4.1891. 'Diversen over Bemesting', NA NHM 7964.

19 Vaclav Smil, *Enriching the earth: Fritz Haber, Carl Bosch and the transformation of world food production* (Cambridge, MA: MIT Press, 2001), pp. 48–50.

20 Thompson, 'Agricultural, chemical and fertiliser industries', p. 1035; John Perkins, 'The agricultural revolution in Germany, 1850–1914', *Journal of European Economic History*, 10, 1 (1981): 71–118.

21 *Archief Suiker*, 'Jubileumnummer 1 Mei 1918'; Margaret Leidelmeijer, 'Van suikermolen tot grootbedrijf: Technische vernieuwing in de Java-suikerindustrie in de negentiende eeuw' (Ph.D. diss., Technische Universiteit Eindhoven, 1997), pp. 231–48.

22 *Encylopaedie van Nederlandsch Oost-Indie*, 2nd edn (The Hague: Nijhoff, 1918), p. 334. The *Encylopaedie* specifically mentions *kacang bungkil, kaliki bungkil* and *kapokpitten bungkil*, the first of which has the highest nitrogen content.

23 K. W. van Gorkom, 'Historische schets van de suikerindustrie op Java', *Tijdschrift Nijverheid en Landbouw in NI*, 23 (1879): 267–8.

24 Cees Fasseur, *The politics of colonial exploitation*, tr. and ed. R. E. Elson and Ary Kraal (Ithaca: Southeast Asia Program, Cornell University, 1992), pp. 26–55 and 86–101.

Wonopringo 'Contract' factory in north-central Java in the 1850s, for example, a new and energetic general manager, Thomas Edwards, began to plan for local purchase of *kacang* ('*in natura*') and the on-site manufacture and sale of its oil, specifically for the purpose of having the residue oil cake readily available for spreading on the factory's cane fields. At the same time, he experimented with *guano*, which his employers imported from Peru, and conducted comparative field trials in combination with *bungkil* and cane ash. He reckoned that oil cake could double productivity in the field and offered his employers a detailed cost analysis of the possibilities.[25] At the close of the 1850s, well over half his factory's fields were fertilised with *guano* or *bungkil*,[26] and mid-way through the 1860s Wonopringo was said to spend some 12–15,000 guilders annually on manure, or between 11–14 per cent of its total production costs in the plantation sector.[27] It was not until the 1880s that experimentation with organic fertilisers would become more widespread.

Chemical *vs.* organic fertiliser

The upsurge in fertiliser use in the 1880s is widely evidenced.[28] Imported *guano*, perhaps the richest single source of organic nitrogen, was one possibility, but a sharp and permanent rise in its price a couple of decades earlier (together with doubts about its efficacy on cane) limited its use.[29] Nonetheless, it would probably have been among the constituents of proprietary fertilisers such as '*Salmonson's Suikermest*' [sugar manure], exported to Java by the Netherlands firm of that name.[30] This was the fertiliser of choice, for instance, of the aggressively 'modern' entrepreneur D. J. Jut. His Soeko Dhono factory in East Java was seemingly established with the precise aim of demonstrating what could be achieved by European 'private enterprise' in the wake of the dismantlement of the *Cultuurstelsel*. Even at Soeko Dhono, however, expensively imported *Suikermest* was confined to ratooned cane (that is, cane grown from the stumps of the previous season's crop), where the outlay could be set against the savings on labour costs contingent on not

25 Anonymous, 'Invloed van guano-bemesting in de suikervelden der fabriek Wonopringo in de Residentie Pekalongan', *Tijdschrift voor Nijverheid en Landbouw in Nederlandsch Indie*, 5 (1859): 33–42; Factorij Batavia to Amsterdam, 25.2.1853/192 2de Afdeeling; 25.6.1853/213 2de Afdeeling; 26.4.1854/284 2de Afdeeling; 23.6.1854/296 2de Afdeeling; 14.2.1855/363 2de Afdeeling, NA, NHM.

26 Factorij Batavia to Amsterdam, 8.8.1859/761 2de Afdeeling, NA NHM.

27 The combined sum of *plantloon*, or crop-pay, paid by the factory to the government (in the form of sugar) of around 90,000 guilders and the fertiliser cost. Sijthoff to Directeur Binnenlands Bestuur, 25.4.1867, Exh. 11.4.1868/91, NA Archief Ministerie van Kolonien 2064; Jaarverslag NHM Factorij Batavia 41 (1865–6), pp. 218–20.

28 For example, the *Koloniale Verslag* ([The Hague: Algemeen Landsdrukkerij, 1883], p.182) contains a comment on 'the annually increasing use of fertiliser on the cane fields', though without further specification. The fullest colonial-era overview of the increase in fertiliser use in Java from the 1890s though to 1914 is W. van Deventer, *De cultuur van het suikerreit op Java. Handboek ten dienste van de suikerreit-cultuur en de rietsuiker-fabricage op Java* (Amsterdam: De Bussy, 1915). This was the fifth volume in a series of Handbooks prepared by industry experts and used in the training – in both the Netherlands and Java – of industry personnel.

29 The London price of *guano* rose 40 per cent between 1852 and 1862; J. M. Mathew, 'Peru and the British guano market, 1840–1870', *Economic History Review*, 23, 1 (1970): 112–28.

30 In 1904, the same firm was advertising 'Ohlendorff''s Soluble Peru Guano . . . Special Fertilisers for Sugar Cane, Tobacco . . . and all other Fertilisers for Tropical Crops', and their availability in Java through agents in Surabaya, Yogyakarta and Semarang; *Handboek voor handel- en cultuur-ondernemingen in Nederlands-Indie* (Amsterdam: De Bussy, 1904).

having to replant cane annually.[31] Jut agreed with his contemporaries in the 1880s in using *bungkil* as his main source of manure. Initially an exclusively local product, during the closing decades of the nineteenth century it also began to be imported in substantial quantities from the Indian sub-continent, from China and from Holland (probably as a re-export from West Africa); between 1880 and 1900 oil cake imports soared from a little over 4 tons annually to 8,000 tons, and probably peaked around that figure (oil cake disappears as a discrete item in customs data in 1903).[32] By the early twentieth century, however, oil cake was entirely outclassed in value by other kinds of fertiliser, mostly chemical and increasingly composed of ZA.

As field manure, the disadvantages of *bungkil* had come increasingly to the fore during the course of the 1890s. In particular, doubts grew apace about oil cake's consistency as a source of nitrogen, at a time when the cost of industrial, chemical alternatives was falling.[33] From the mid-1880s onward, the industry's newly established West Java Research Station at Kagok in Tegal began trials with chemical fertilisers, using superphosphate, potassium nitrate [*chilisalpeter*] and potassium sulphate [*Zwalvelzuur Kali*] alongside oil cake. It was only toward the end of the 1880s, however, that sulphate of ammonia began to feature significantly in these trials, with experiments taking place at a number of factories in neighbouring locations. The immediate impetus for extended trials with ZA appears, however, to have come from the *Vorstenlanden* [Principalities] of the 'interior' of Central Java, where the chemical was found by the early 1890s to be highly effective on light, sandy soils in particular. The leading figure in pioneering its use there was reportedly the director of the Klaten Research Station (Surakarta, Central Java), C. J. van Lookeren Campagne.[34] By 1893, the industry was already being strongly urged to carry out extensive investigations of the possibilities of ZA.[35] At the same time, experts at the Research Stations had concluded, as far as it was possible to generalise, that while the silt-enriched soils of Java's sugar fields had sufficient phosphates and potassium to meet cane's requirements, the same was only very rarely ['*vrij zeldzaam*'] the case with nitrates.[36] Taken together, these findings paved the way for the rise of ZA to become the fertiliser of choice of Java's colonial sugar manufacturers.

First and foremost, the price was right. Between 1880 and the early 1890s, the British (and hence international) price of sulphate of ammonia had fallen by almost 50 per cent, from £20 per (long) ton to just over £11. The price bottomed out in the late 1890s at around £7.50S.[37] Largely through the agency of the sugar companies themselves and their associated businesses, imports of chemical fertiliser, most of it from the United

31 D. J. Jut, *Nota over de grondbewerking en bemesting van suikerriettuinen, zo als die worden uitgevoerd voor de vrije suikerfabriek 'Soeko Dhono', te Modjo Agoong, afdeeling Modjo Kerto, Res. Soerabaia op Java* (31.12.1881), n.d., n.p.

32 Shannon R. Brown, 'Cakes and oil: Technology transfer and Chinese soybean processing, 1860–1895', *Comparative Studies in Society and History*, 23, 3 (1981): 449–63.

33 J. D. Kobus, 'Proeven omtrent plantwijdte en bemesting bij suikerriet', *Archief Suiker*, 9, 2 (1901): 635–48.

34 *Archief Suiker*, 6, 1(1897): 412–56.

35 J. D. Kobus, 'Bemestingsproeven. . . Sourabaia 28.7.1893', *Archief Suiker*, 1 (1893): Bijl. 3.

36 H. C. Prinsen Geerligs, 'Iets over de bemesting van de suikerreit', *Archief Suiker*, 1 (1893): 190; Van Deventer, *Suikerreit-cultuur*, pp. 405–8.

37 *Bradbury and Hirsh's review of the market for sulphate of ammonia during 1890* (London, 1891); J. R. Partington and L. H. Parker, *The nitrogen industry* (London: Constable, 1922), pp. 125, 129–31.

Kingdom, the Netherlands and Germany, boomed.[38] Between 1880 and 1900, such imports increased nearly ten-fold in value from less than 0.5 million guilders per year to somewhat under five million (quantities are so erratically recorded for this period as to vitiate comparison in terms of volume). By 1901, fertiliser imports of this kind into Java were worth around eight times as much in value as oil cake (4,230,882 as opposed to 651,000 guilders).

Within Java, meanwhile, a network of rail, light rail and tramways was sufficiently evolved by 1900 for chemical fertiliser to be distributed conveniently and cheaply to virtually any part of the island. While sugar remained their single most valuable item of bulk haulage, fertiliser (in its organic and chemical forms) became an important item of business for such railway companies as the Ciribon-Semarang *Stoomtram* [Steam Tram], whose lines by 1900 serviced the great majority of the sugar factories located along the north coast of Central Java. The *Stoomtram*, which had been carrying increasing quantities of oil cake along its lines since its records began early in the 1890s, switched over to ZA in a big way during the first decade of the new century, such that by 1908 it was carrying around 7,000 tons of the fertiliser on its lines along the north coast of Central Java, and by 1913 was carrying some 11,000 tons.[39]

Around 1900 it could still be remarked that some factory managers still preferred *bungkil* to ZA, despite the fact that 'almost all experiments with fertiliser' had proved ZA's greater efficacy and cost-efficiency.[40] *Bungkil* continued to have a role to play as a *voormest* that is to say, a manure dug into the ground before the crop was planted. Shortly after the turn of the century, however, ZA was already being hailed as the ubiquitous fertiliser of Java's cane fields.[41] A decade later the fertiliser was authoritatively described as 'of indispensable importance for the agriculture of sugar' and as 'the most used and the foremost among the nitrogen combinations consumed in the Indies'.[42] Application rates per hectare rose sharply in the early years of the twentieth century. At many factories, rates doubled in the decade prior to 1914, by which time the average on Java was nearly four quintals for every hectare of cane (use peaked a decade later at over five quintals).[43] ZA itself was only separately itemised in the Netherlands Indies customs data from 1909 onward: between that year and 1914 imports of the chemical quadrupled in value, from a little over two million to over eight million guilders.[44] As such, by the eve of the First

38 Leidelmeijer, 'Suikermolen tot grootbedrijf', p. 232; *Handboek voor cultuur – en- handelsondernemingen in NI*, 1903 (15), p. 778, and 1925, p. 1469.

39 See Jaarverslagen van de Chef der Exploitatie, 1895–1914, Dossier 008, Archief Semarang-Cheribon Stoomtram Mij., NA .

40 Kobus, 'Proeven omtrent plantwijdte en bemesting bij suikerriet', p. 635.

41 P. van Houwelingen, 'Over de waarde der meststoffen', *Archief Suiker*, 10, 1 (1904): 572–6. England is identified as the biggest single supplier – 19,280 tons in 1903 (or 3,110,000 picul) at a cost of 16 guilders the quintal or 10 guilders the picul.

42 Van der Leemkolk, 'Gebrek van meststoffen', 99.

43 Van Deventer, *Suikerreit-Cultuur*, p. 408. Use peaked around a decade later, when the average figure was nearly 5.2 quintals per hectare (6 piculs per *bau*), with more than twice that rate in some locations; G. Booberg, 'Korte mededeelingen van het proefstation voor de Java-suikerindusrie. No. 82. Bemestingresultaten bij de suikercultuur, *Archief Suiker*, 35, 1 (1927): 431–46.

44 *Statistiek van den handel, de scheepvaart en de in- en uitvoerrechtegten in Nederlandsch Indië over het jaar . . . samengesteld bij het Departement van Financiën* (Batavia, Landsdrukkerij, 1880–1908); *Statistiek van den handel en de in- en uitvoerechten in Nederlands-Indië over het Jaar. . . /Samengesteld bij het hoofdbureau der in- en uitvoerrechten* (Batavia: Landsdrukkerij, 1909–14).

World War (which threatened to jeopardise its supply), ZA accounted for around five per cent of the total value of all non-government imports into the Netherlands Indies as a whole.

Fertiliser in the framework of industrial agriculture

The supply side was one dimension of the Fertiliser Revolution in Java's late colonial cane fields. The other was the degree to which it became embedded in a broader framework of industrial agriculture in which fertiliser inputs were a key but by no means unique element. Ultimately, the Revolution was made possible by a number of factors related to the changing political economy and agrarian context of sugar production in late nineteenth-century Java, the net result of which was the evolution of a totally singular plantation regime. Heavy inputs of labour, allied to closely supervised industrial work routines characterised by task work and an elaborate division of labour, were combined with globally unsurpassed scientific attention to agriculture, horticulture, irrigation and pest control. Fertiliser combined with science and labour to produce an industrial synthesis in the cane field that placed the Java plantation firmly within the parameters of modern capitalist production.

A crucial development was a restructuring of the industry, associated with the phasing out of the *Cultuurstelsel*, which ensured that factory and field became an integrated unit of manufacture. Until then, the formal dichotomy established in the 1830s between contractor-manufacturers on the one hand, and the state supervision of cane production on the other, continued to hold. From 1880 onwards, however, the factories previously contracted to the Indies government began to take direct charge of the agricultural as well as the manufacturing sectors of production. Under the new dispensation, cane continued, as of old, to be grown (for the most part) on peasant land, but this land was now rented by the factories from village landholders on a periodic basis and consolidated into large plantation blocks. Such linkages between cane production and 'village' agriculture as existed under the *Cultuurstelsel*, when cane was raised for the factories by peasant farmers at the behest of the state and under the direction of their own headmen, were progressively severed. In this sense, the real novelty of the post-1880 situation lay in the extent to which cane cultivation, and all that appertained to it, was now entirely removed from the sphere of peasant agriculture. The existing system of two-, three- or even four-year rotation between sugar cane, rice and other peasant crops, devised under the *Cultuurstelsel*, remained in force. Work in the cane fields was now carried out, however, by the wage labour of 'part-time' peasants or quasi-proletarians (the distinction is largely semantic), working under the direct supervision of the factory's European/Eurasian plantation overseers (*tuinopzichters*) and their teams of Javanese foremen (*mandoors*). It is possible, but ultimately nonsensical, to gloss this change (as Clifford Geertz did in his speculative treatment of the subject some 50 years ago) as representing a continuation of cultivation on peasant land using peasant labour, now under the direction of capitalists rather than state officials. *Inter alia*, the elaborate division of labour, important developments in the gendering of the workforce and the highly evolved nature of supervision (all of which are detailed here) that characterised the industrial plantation of late colonial Java serve to nullify the simplistic notion that the late colonial plantation merely experienced a change of masters.

Indeed, it was this new, direct farming of cane that evolved late in the nineteenth century, characterised not only by the common management of factory and field but also by an increasingly meticulous attention to every aspect of agriculture, that singled out the Java industry from virtually all of its global counterparts. Only Hawaii and (possibly) Peru, both much smaller industries, approached it. In Cuba, Java's Occidental counterpart, the agricultural sector of production was famously neglected. Elsewhere in the New World, it was generally only in the 1920s that concerted and consistent attention was paid to cane, while in Asia itself, only on the Indian Ocean island of Mauritius was serious attention devoted to the field science of sugar, and that effort had largely collapsed by 1914.[45] In the case of the Philippines, Java's nearest and largest Asian counterpart, modernisation in the factory was paired with a plantation sector in which agricultural development on the Java model was effectively stymied by the fragmentation (tenancy and sub-tenancy) of holdings in the agricultural sector.[46] Outside the immediate region, the sugar industry of northeastern Australia established a respectable record in agricultural science from the late nineteenth century onward, but in terms of size it was dwarfed by the industry in Java.[47]

Labour intensive industrialisation

Underlying the Fertiliser Revolution at a fundamental level was the combination of direct farming with a transformation of field labour through its enmeshment within work routines of a distinctly industrial character. This transformation has been partly obscured by the fact that Java's colonial sugar producers entered the age of mass production with a potential labour force whose size and low-cost character made them the cynosure of rival industries. Java was famed for having 'the cheapest labour among the sugar producing countries of the world', and for being a territory where, in contrast to the norm, it was labour rather than land which was 'so abundant and cheap'.[48]

Nonetheless, in so far as this conjures up images of limitless numbers of cheap 'coolies' working in a labour-squandering regime, it is well wide of the mark. Considered in isolation, the cheapness and availability of labour did not account *per se* for the burgeoning of sugar production in late colonial Java. Rather, the comparative advantage enjoyed by the industry stemmed from the manner in which the labour 'bonanza' was exploited for essentially industrial purposes. The evolution of industrial agriculture has been commonly equated with the advance of the machine and the (partial) suppression of manual labour. Late colonial Java stands as a contrary instance. Industrialisation was located in work processes rather than in machines, and mechanical solutions to

45 W. A. Castens, *Een reis naar de Hawaii Eilanden in 1900–1901* (Soerabaia: H. van Ingen, 1902), pp. 40–5; Bill Albert, *An essay on the Peruvian sugar industry 1880–1920 and the letters of Ronald Gordon, administrator of the British Sugar Company in Canete* (Norwich: University of East Anglia, 1976); Dye, *Cuban sugar*, pp. 241–4; McCook, *States of nature*; J. A. Heitman, *The modernisation of the Louisiana sugar industry* (Baton Rouge: Louisiana State University Press, 1987), pp. 62; Storey, *Science and power*, pp. 69–96.

46 *Facts and statistics about the Philippine sugar industry*, ed. G. H. Fairchild (Manila: Sugar News Press, 1928), p. 53.

47 Peter Griggs, 'Improving agricultural practices: Science and the Australian sugarcane grower, 1864–1915', *Agricultural History*, 78, 1 (2004): 1–33.

48 Francis Maxwell, *The economic aspects of cane sugar production* (London: Norman Rodger, 1927), p. 7; H. C. Prinsen Geerligs, *The world's cane sugar industry* (Altricham: Norman Rodger, 1912), p. 124.

agricultural problems played only a minor part in the changes that took place.[49] Growth was based on a labour-intensive yet simultaneously industrial regime. Within the parameters of the intensive exploitation of manual labour, the essentials of industrial production came to be found as much in the field as the factory.

Absolutely integral to this development was a radical, late nineteenth-century shift in the gender composition of the workforce. It was a question not only of the 'availability' of labour but also of the kind of labour available. Women and children began to enter the formal workforce as never before. They did so, at least in part, as a consequence of a concurrent downturn in the fortunes of peasant agriculture, marked by what one historian has referred as the 'stubbornly low' price of rice, which appears to have forced large numbers of women and children to seek wages 'outside the village'.[50] Whatever the causes (and agrarian conditions in rural Java in the late nineteenth century are urgently in need of further investigation), the effect was that women and children were found working alongside men in both sugar fields and factories to an extent that colonial contemporaries regarded as unprecedented.[51] It meant that the increased availability (and reliability) of industrial fertiliser largely coincided with a period in which the cheap labour of women and children was also available on a scale hitherto unknown.[52] In turn, this enabled elaborate routines of fertiliser application to be put in place at minimal cost. Women and children were also heavily involved in the planting of cane, so it is difficult to provide discrete numbers for those involved in the fertiliser programme alone.[53] In total, however, they came to form a substantial part of the industry's workforce: at one north coast factory (Katangoengan-West), which there is no reason to suppose was exceptional, in June 1908 – a peak month of activity – there was a daily average of 1,119 women and 899 children working in the plantation, together with over 3,000 men.[54] The success of the Fertiliser Revolution was largely predicated on them.

Commensurate with the influx of women and children into the sugar workforce, as keen-eyed colonials were quick to note, was an all-round reduction in wages and an increased facility on the part of management for subordinating the industry's workforce as a whole. Around the turn of the century, it was widely reported that wages were considerably lower than had been common in rural employment only a few years

49 One exception is related to haulage. Manufacturers began to lay rails to connect field to factory as early as the 1860s, and by the early twentieth century the miniature, wood-burning locomotive, drawing a string of trucks full of cane, was a common sight in the neighbourhood of most of the island's colonial sugar factories. By the 1920s, the industry boasted some 10,000 kilometres of rail track; H. Ch. G. J. van der Mandere, *De Java-suikerindustrie in heden en verleden* (Amsterdam: Bureau Industria, 1928), p. 57.

50 Elson, *Javanese peasants and the colonial sugar industry*, pp. 137–41; Anne Booth, *Agricultural development in Indonesia* (Sydney: Allen and Unwin, 1988), pp. 30–40; Pierre van der Eng, *Agricultural growth in Indonesia: Productivity change and policy impact since 1880* (Basingstoke: Macmillan, 1996).

51 See *Onderzoek naar de mindere welvaart der inlandsche bevolking op Java en Madoera . . . Gewestelijk onderzoekingen naar de economie van de desa*, 15 vols. (Weltevreden: various publishers, 1906 etc.) (hereafter cited as *OMWED*). See, e.g., *OMWED . . . Banjoemas*, p. 46 and *OMWED . . . Kediri*, p. 57.

52 Peter Boomgaard, 'Female labour and population growth on nineteenth century Java', *Review of Indonesian and Malayan Affairs*, 15, 2 (1981): 1–31.

53 At many factories, such as Soeko Dhono in early 1880s, cane planting was quite explicitly women and children's work (Jut, *Nota over de grondbewerking*).

54 Jaarverslag Sf. Ketanggeongan-West, 1908, pp. 3–4; 1911, p. 11; 1913, p. 10, NA NHM 9210; Philip Levert, *Inheemsche arbeid in de Java-suikerindustrie* (Wageningen: H. Veenman and Zonen, 1934), pp. 119–21 and 125–7.

earlier.[55] Women and children, in particular, were described as 'scandalously badly paid'.[56]

On this basis, a situation evolved fairly rapidly in the final decades of the nineteenth century in which the regimented, closely supervised and task-differentiated labour of large numbers of workers could be brought to bear on every aspect of the production of cane. Following the end of servile, state-commandeered labour in the island's colonial cane fields in the course of the 1880s, the sugar factories had opted to remunerate their largely casual field workforce by the day or more frequently by the job. By the early twentieth century, the industry's field workforce carried out task-work which might be divided into as many as 16 categories, and was itself categorised in a variety of forms extending from 'gully coolies' (the people who dug out with hand tools the trenches in which cane was planted) through to the 'weed women' who kept the growing cane free of undergrowth.[57] With respect specifically to fertiliser, the work process was an elaborate one, dependent on regular, well-documented and highly labour-intensive routines for ensuring that the fertiliser penetrated the soil around the roots and that it did so in appropriate rather than merely random quantities. As early as 1882, for example, Jut was able to report that at his 'progressive' Soeko Dhono factory in East Java the procedure was for fertiliser to be carried by children in baskets along the rows of cane, and strewn around each plant in a measured amount, after which a 'coolie', following behind, worked the fertiliser into the ground with a *pacul* (a spade-cum-hoe indigenous to Java).[58] According to an account published in 1901 – and evidently intended both as description and as guide to those who might be new to the use of ZA – at many factories the fertiliser was first mixed with water in a bamboo container or box. Subsequently, woman worked their way through the rows, delivering a fixed measure of the liquid fertiliser to each clump of cane. The writer thought that it might pay, at least on heavier soils, to first make a hole near the plant, into which the liquid might be poured.[59] Subsequent reportage was of routines that involved two, three or even four successive doses of fertiliser during the course of the season. At some factories dosage was standardised in the form of tablets of compressed ZA, for which purpose a Dutch firm invented a small machine to enable them to be fabricated on the spot.[60] Fundamental to the whole programme was the work of the industry's Research Stations in conducting extensive field tests to gauge the optimal application rates of sulphate of ammonia in the context of the key variables of soil and climate. In 1914 alone, there were 223 such tests recorded and by the 1920s this figure had doubled or even trebled.[61]

55 *OMWED . . . Pekalongan*, p. 46; Nico Dros, *Wages 1820–1940: Changing economy of Indonesia*, vol. XIII (Amsterdam: Koninglijk Instituut voor de Tropen, 1992).

56 *OMWED . . . Sourabaija*, p. 161.

57 Jaarverslag Sf. Wonopringo (Pekalongan) 1913, p. 4, NA, NHM; G. Roger Knight, 'Gully coolies, weed-women and *snijvolk*: The sugar industry workers of North Java in the early twentieth century', *Modern Asian Studies*, 18, 1 (1994): 51–76.

58 Jut, *Nota over de grondbewerking*.

59 C. Bruyn, 'Eene opmerking over het mesten met zwavelzuur ammonia', *Archief Suiker*, 9, 1 (1901): 460–1; Jaarverslag Sf. Poerwodadi (Madiun), 1910: 4, NA NHM 9391.

60 Van Deventer, *Suikerreit*, p. 417.

61 Booberg, 'Bemestingsresulten', pp. 434–5. The fundamental reason for the long-term continuation of tests was to determine the optimal application rate of ZA in locally very varied and annually changing conditions.

Informed and informing supervision

As with other aspects of industrial fieldwork, the key to the success of this elaborate fertiliser programme was an informed and informing system of supervision that enabled 'cheap' labour to be transformed into the basis of large-scale, low-cost production. In turn, supervision on the requisite scale was feasible because Java's large and old established Eurasian Dutch communities, legally and socially assimilated as *totok*, expatriate arrivals from metropolitan Europe, provided recruits whose ostensible familiarity with 'the natives' purportedly gave them an edge over Dutch expatriates. Late in the 1880s, the industry's Semarang Research Station held a training course 'where youths, born on Java, will obtain the knowledge necessary for the growing of sugar [*suikerteelt*]'.[62] A survey done some 40 years later confirmed that the great majority of the industry's Dutch field employees were Java-born – and therefore preponderantly Eurasians.[63] By that date, they were the recipients of fairly standardised formal and experiential training, as well as the object of industry-run 'refresher' courses. In 1926, for instance, the main Research Station at Pasuruan in heart of the East Java sugar belt, hosted a seven-day '*Cursus*' for Cane Planters, whose educational programme was provided at the industry's expense.[64] The functions of those trained were not confined simply to the supervision of workers: they were also crucial to the assembly of the data on which 'scientific' production depended. In the early 1880s, for example, Jut's field supervisors at Soeko Dhono had already been expected to submit 10-day written reports on a pre-printed, standardised form, and arrangements of this kind had become *de rigueur* throughout the industry by the century's end.

Nonetheless, in the final analysis it was the presence of the 'native' field staff that made possible the in-depth supervision of the plantation. The industrial agriculture of cane was ultimately dependent, in short, on the availability of increasing numbers of young Indonesians whose educational standard enabled them to aspire to better themselves by finding supervisory employment with European enterprises. By the end of the 1920s, the industry employed some 23,000 Indonesian field supervisors, on an average ratio of roughly one full-time individual for every nine hectares of standing cane.[65] Photographs of the Dutch *Tuin-employee* and his cohort of a dozen or more Indonesian assistants became a standard feature of the industry's archive, as did photographs of the plantation-in-the-making, its landscape dotted with the white-clad figures of 'native' *mandoors*.

Managerial culture, research and development

A key element in the implementation of the Fertiliser Revolution itself was that it took place within the context of a gathering managerial culture that placed a high value

62 See 'Proefstations voor suikercultuur', *Tijdschrift voor Nederlands Indie* (niewe reeks), 15, 1 (1886): 218–22.

63 J. J. Tichelaar, 'De ge-employeerde in dienst der Java suikerindustrie, en hunne opleiding', *Archief Suiker*, 32, 2 (1924): 1197–212, 33; and 1–2 (1925): 21–9, 1210–24,1433–7.

64 'Cursus voor rietplanterss 1926', *Archief Suiker*, 34, 1 (1926): 7–9.

65 In 1930 there were 12,738 '*tuinmandoors*' [plantation foremen] and 10,308 '*hulp tuinmandoors*' [assistant plantation supervisors] employed in the colonial Java sugar industry. In the same year, the (harvested) area under cane amounted to nearly 200,000 hectares; *Indisch verslag* (Batavia: Centraal Kantoor voor de Statistiek van het Departement van Economische Zaken, 1934), vol. II, p. 192.

on Research and Development. There were pressing immediate, historical reasons for a late nineteenth-century interest in research and development, not least being the relatively limited area of land which the Java industry had available to it and its precarious position in an international sugar economy where it alone of the world's major producers had no large and secure (quasi-) metropolitan market. It was also, of course, an enterprise that served to legitimise colonial agriculture by attempting to demonstrate the neutral or even benign effects of agro-chemicals.[66] The upshot was a record for innovation in field science that made the Java industry the envy of its counterparts elsewhere in the international sugar economy. 'It is in Java, however, that the scientific study of the cane has reached its highest form', remarked one of the international sugar industry's most respected experts a few years before the First World War.[67]

The industry itself certainly saw it that way. In the late 1880s the various sectors of the industry had collaborated – initially somewhat grudgingly – in setting up a network of Research Stations (*Proefstations*) linked to what became the central institution in Pasuruan, at the hub of the East Java sugar belt.[68] The same decade saw the first publication of the *Archief voor de Suikerindustrie* as the manufacturers' monthly journal. Replete from its beginnings in 1893 with information not only about the technology of manufacture but also about the latest findings relating to the agriculture and horticulture of cane, by the third year of its existence (1895) the *Archief* counted among its subscribers 147 sugar factories and associated businesses, 430 factory managerial and technical personnel [*geemployeerden*] and 74 'private' individuals.[69] Significantly enough, by the mid-1920s the *Archief* had notched up sufficient articles and references to field fertiliser to fill seven double-column pages of its cumulative index. Before the outbreak of the First World War, the *Archief* had already comprised 'no less than forty massive volumes', and, as such, was a testimony to the 'gigantic work which has been carried out' and to 'the energetic way in which the industry is carried on'.[70] Well might the industry's leading contemporary *savant*, H. C. Prinsen Geerligs, remark that:

> Though it is a common saying in Europe that in the tropics the work is done in a rather careless manner, we do not deserve such a reproach in Java, as everything which science and experience can suggest to us as advantageous for our industry is investigated and tried, as well in the field as in the factories, and in the laboratories of the experimental stations supported by subscriptions from the sugar estates.[71]

In short, the Fertiliser Revolution and the larger programme of research and development that surrounded it reveals an industry bedded down in field (as well as factory)

66 Wim J. van den Schoor, 'Pure science and colonial agriculture: The case of the private Java Sugar Experiment Stations, 1885–1940', *Journal of the Japan-Netherlands Institute*, 6 (1996): 75–6; Suzanne Moon, 'The conflict over sugar/rice ecology in the Netherlands Indies, 1905–1914', *Environment and History*, 10, 1 (2004): 59–81.

67 Noel Deerr, *Cane sugar: A textbook of the agriculture of the sugar cane, the manufacture of cane sugar and the analysis of Sugar House products* (Altrincham: Norman Rodger,1911), p. vi.

68 Hermono Budhisantosa *et al.*, *Indonesian Sugar Research Institute. One hundred and ten years of science, July 9, 1887–1997* (Pasaruan: n.p., 1997); Harro Maat, 'Science cultivating practice: A history of agricultural science in the Netherlands and its colonies, 1863–1986' (Ph.D. diss., Wageningen Universitiet, 2001).

69 'Voorword', *Archief Suiker*, 3, 1 (1895): 1–2.

70 Arnold Wright, *Twentieth century impressions of Netherlands India* (London: Lloyd's Greater Britain Publishing Company, 1909), pp. 359–62.

71 H. C. Prinsen Geerligs, 'The sugar industry in Java', *The International Sugar Journal*, 6 (1904): 339.

science. The industry applied this science to agriculture several decades before almost any of its global counterparts. Prior to the 1920s, only the much smaller American industry in Hawaii approached Java in this respect. A telling point about even Hawaii, moreover, was that in the early twentieth century researchers there found it necessary to employ a woman conversant with the Dutch language specifically to translate reports of the latest research from Java. Dutch visitors before the First World War could hardly conceal their delight at finding copies of Geerligs' publications in the laboratories of many factories in Hawaii.[72]

Yielding to none: Unparalleled success in the field

The Fertiliser Revolution and associated development of industrial agriculture had far-reaching consequences for the Java industry's location in the international sugar economy. Over a 20-year period ending in 1913, the island's total output of sugar increased three fold, from 5,000,000 to 15,000,000 metric tons,[73] which meant that on the eve of the First World War, Java more than held its own, along with Imperial Germany and Cuba, in the topmost rank of the world's exporters of sugar. The crucial aspect of the Java industry's late nineteenth and early twentieth-century expansion, however, was less a matter of the sheer quantity of sugar produced than of the history of the industry's plantation yields. These had been globally high from around the mid-nineteenth century onward, but between 1890 and 1910 they showed an increase of more than 50 per cent, from less than 68 to around 105 tons of cane per hectare.[74] The difference on this score between Java and Cuba, its New World coeval, is particularly striking. Whereas the Java industry entered the twentieth century with substantially improving plantation yields, in Cuba the reverse took place: between the 1880s and the eve of the First World War, per hectare productivity in the agricultural sector declined significantly.[75]

Improved cultivation techniques played a role in Java's success. One of the facets of the evolution of industrial agriculture was the increasing adoption throughout the industry of meticulous and labour-consuming methods of planting cane. The Reynoso system, or one of its variants, had been practised at some factories since the 1870s but only became widespread early in the twentieth century. It called for the planting of cane in deep trenches, the main advantage of which was that the young plants experienced more extensive root growth than was the case with shallow cultivation in land that was simply ploughed. The system was devised in Cuba in the 1860s, but was most extensively taken up in places like Java where the workforce was adequate to the heavy inputs of manual labour that it required.[76] Likewise, some part in the achievement of globally unsurpassed plantation yields can be ascribed to new cane varieties, in so far as the Java industry itself produced a long sequence of them from the 1890s onward. Initially, however, the prime

72 J. W. Ramaer, *De arbeidstoestand op de Hawaii-Eilanden, Voorafgegeven door een reisverhaal en enkele aantekeningen omtrent de suikerindustrie op die eilanden* (Amsterdam: De Bussy, 1913), p. 12.
73 P. Creutzberg, *Changing economy in Indonesia, volume 1: Indonesia's export crops 1816–1940* (The Hague: Nijhoff, 1975), pp. 74–5.
74 W. C. Dickhoff, 'De Java suikerindustrie gedurende de tijdvak 1894–1913', *Archief Suiker*, 22, 1 (1914): 613–14.
75 Cesar J. Ayala, 'Social and economic aspects of sugar production in Cuba', *Latin American Research Review*, 30 (1995): 95–124.
76 Van Deventer, *Suikerreitcultuur*, pp. 224–53.

role of cane horticulture was to produce disease resistant varieties, as well as ones suited to the very various soil conditions which the industry encountered as the massive, late nineteenth-century expansion of the area under cane got under way.[77] Broadly speaking, it was only after 1914 that new varieties began to have a significant impact on productivity *per se*, a trend which reached its culmination in the late 1920s with the introduction and rapid take-up of POJ 2878, Java's 'Wonder-cane', propagated by the East Java Research Station and possessing a potential to triple plantation yields. Until then, it was the soil rather than what was planted in it that was the dominant factor in determining field productivity.

The history of cane yields in late nineteenth and early twentieth-century Java is complicated by two factors: the prevalence of cane disease in the late 1880s and uncertainly about the standard measurement of land – and hence of yields – prior to the late 1890s. The former had the effect of 'artificially' reducing cane yields while the latter had the effect of inflating them. The precise extent of the damage wrought by cane disease (*sereh*) on the agricultural sector of production is ultimately unquantifiable; it was widely reported for ten years after 1885, but in any given year varied very considerably in its impact on different localities. During the 1890s *sereh* was largely defeated, apparently as the result of the introduction of new cane varieties and, probably most important of all, by the elaboration of a system of cane propagation heavily based in the use of cuttings (*bibit*) brought in from outside the immediate area of production. The consequent recovery in the plantation undoubtedly distorts the picture of cane yield growth in the 1890s, but to a degree makes it virtually impossible to ascertain. It seems reasonable to assume, however, that cane yields in the early 1890s – the starting point for comparisons – were lower than 'normal' thanks to the inroads of cane disease.

Contemporaneously, however, there were factors at work that meant that 'normal', pre-*sereh* plantation yields were themselves distorted by causes that need to be taken into consideration if the achievements of the Fertiliser Revolution from the 1890s onward are to be properly assessed. One of the late nineteenth-century Java industry's many inheritances from the *Cultuurstelsel* was an idiosyncratic system of measuring the amount of land planted to cane in either net (*netto*) or gross (*bruto*) hectares, the latter usually at least ten per cent greater in extent than the former in order to allow a generous margin for drainage ditches, tracks and other necessary modifications to rice land to enable its efficient conversion into sugar plantation. In addition local usage varied considerably in nineteenth-century Java as there were just too many parties with an interest in turning a blind eye to the exact amount of land actually engrossed by cane. Very real doubts about the standardisation or accuracy of land measurement present difficulties for comparisons of yields across time. In particular, the persistence late into the nineteenth century of the net hectare as the standard measure of plantation yields creates the illusion that yields in the 1880s and early 1890s were higher than they actually were in comparison to subsequent yields recorded when the gross hectare had become the standard, industry-wide norm.[78] Nonetheless, the upshot of comparisons, corrected as far as is possible for these various anomalies in the data, points to some clear conclusions. Although plantation

77 Ibid., pp. 329–58.
78 W. C. Dickhoff, 'De Java suikerindustrie gedurende de tijdvak 1894–1898', *Archief Suiker*, 8, 1 (1900): 173–4, 183–4.

yields broadly commensurate with the results obtained Java-wide once the Fertiliser Revolution had got underway in the course of the 1890s had been achieved at select locations a full decade or more earlier, the overall effect of the Revolution was to bring about a doubling of plantation yields in the colony as a whole over a period of less than 20 years. The critical point, moreover, was that this prodigious increase took place in circumstances that might otherwise have been detrimental to plantation productivity.

Collating the data from the relatively small number of factories for which information is available in the early 1880s suggests that pre-*sereh* yields averaged around 70 tons per ('*bruto*') hectare, and on occasion might be as high as 94 tons.[79] Yields like these were not seen again until the Fertiliser Revolution was well under way, but they must be judged exceptional as reflecting both the output of highly suitable land and, most importantly, the best efforts of a number of uncommonly well-managed factory-plantation units.[80] A more realistic figure, based on both contemporary observation and data suggests that, Java-wide, the pre-*sereh* plantation yields of the early 1880s were more likely to have been in the region of 55 tons per (*bruto*) hectare. Assuming this figure to be broadly correct, it suggests when reasonably reliable industry-wide data for field productivity began to become available in the mid-1890s, the Fertiliser Revolution and associated developments in cane cultivation had already begun to make a significant impact. Average yields in Java as a whole were calculated for 1894 at around 68 tons per '*bruto*' hectare. It was during the following decade and a half, however, that the Fertiliser Revolution made by far its greatest impact. Between 1894 and 1908, average plantation yields in the colony as a whole rose some 65 per cent to a peak of 105 tons of cane per hectare, resulting in a level of field productivity in Java totally unequalled elsewhere in the international economy of cane sugar.[81]

The critical significance of this increase, however, is that it coincided with a very considerable expansion – from 34,500 hectares in 1880 to 147,500 hectares in 1914 – of the area under cane.[82] As we have seen, there is evidence that fertiliser played a significant part in sustaining and improving yields in areas where the soil had been 'exhausted' by decades of cane-planting. In some parts of the Americas, as in parts of the Asia-Pacific region, late nineteenth and early twentieth-century expansion took sugar into (notionally) virgin soils whose assumed fecundity was sufficient to maintain or enhance overall plantation yields, at least in the short term. Alternatively, as appears to have been the case in Cuba, where plantation yields declined considerably during the early years of the twentieth century, extensification of cane production went in tandem with a fall-off in field productivity because it became economically rational to pay less attention to

79 Eight factories were in the range of between 69 and 104 tons of cane per ('*netto*') hectare, with an average over four years of around 78 tons. The figures cited have been corrected by a factor of ten per cent to bring them into line with the '*bruto*' hectare calculations prevalent at the end of the century.

80 The factories from which this data are derived are: Kemantran, Maribaija, Doekoewringin (Tegal); Wonopringo, Tirto, Klidang (Pekalongan); Poerwodadi (Madiun); Soekodhono (Surabaya). See NA NHM, 3672 'Cultuurzaken. . .Ramingen en Resultaten Eigen Fabrieken c. 1879–1900; from 'NHM Inspectie-Rapporten over Eigen en Andere Ondernemingen, 1879–1900' NA NHM 3673; 'Poerwodadi tot 1888' in Dossier Overzicht Poerwodadi van 1878–1885, NA NHM 7944; Dossier 'Doekoewringin tot 1897' Rapport over de Sf. Doekowringin. . . Tegal, Januari 1888, NA NHM 7942.

81 Maxwell, *Economic aspects*, pp. 50–8.

82 Creutzberg, *Export crops*, pp. 74–5.

cultivation on the (correct) assumption that sheer quantity would make up for the lack of quality.[83]

In contrast, the single most important achievement of the Fertiliser Revolution in Java was to ensure that the (relatively) high yields obtained in favoured locations in the 1880s and (probably) earlier were carried over and improved upon in locations that were distinctly less favourable to the cultivation of cane, such as existing rice land which the industry had previously eschewed, new areas where 'technical irrigation' had brought regular water to land previously farmed as *tegal* (dry-crop land), and drained land previously too swampy for any form of agriculture. As one factory *administrateur* in Central Java reported early in the new century, 'sugar production has increased substantially in recent years, despite the circumstance that the plantation has been expanded into what was formerly considered to be unsuitable soil'.[84]

By the eve of the war the impact of the Fertiliser Revolution on plantation productivity – and on the output of processed sugar – appeared to have run its course. Average cane yields in the Java industry peaked around 1908 and thereafter either stagnated or even showed signs of decline. The program of intensive applications of ZA had reached the limits of its potential. The Fertiliser Revolution itself had reached the point where the plantation no longer responded to greater chemical inputs. Indeed, the sheer volume of input may have started to become counter-productive, since an excessive application of fertiliser tended to produce more growth than sugar content. Secondly, as sources within the industry were careful to note, the massive increases in the volume of cane per hectare that had been produced over the previous decade had not been matched by any commensurate rise in its sugar content. Worse still, it was beginning to look as if the sugar content of cane was actually falling off.[85]

Fertiliser and the cost of field production

Fertiliser represented a very substantial part of the industry's capital outlay. Just how great that outlay was before the closing years of the nineteenth century is hard to judge given the highly fragmentary nature of the evidence and the diversity and inconsistency of accounting methods at the time. Some old – 'Contact' – factories were already making substantial outlays on fertiliser of one kind or another during the course of the 1880s, as control of the plantation was progressively taken over from the Indies government (see above). At one such factory in Central Java during the 1886–7 season, for example, it looks as if fertiliser accounted for over 20 percent of total outlays on the 'private' (non-government) sector of the plantation.[86] This may have been an exceptional situation in the 1880s. Toward the end of the nineteenth and in the opening years of the twentieth centuries, however, we can be fairly confident that fertiliser accounted for at least one-sixth of expenditure on inputs in the agricultural sector at many of Java's colonial sugar factories. This expenditure, moreover, did not include the labour component of the fertiliser programme, which probably brought the total figure nearer to 20 percent.

83 Ayala, 'Social and economic aspects', pp. 104–6.
84 Jaarverslag Sf. Poerwodadi (Madiun) 1906 (unpaginated), NA NHM 9321.
85 Dickhoff, 'De Java suikerindustrie 1894–1913', pp. 615–16.
86 'Inspectie-Rapporten over Eigen en Andere Ondernemingen, 1879–1900' (unpaginated). NA NHM 3673.

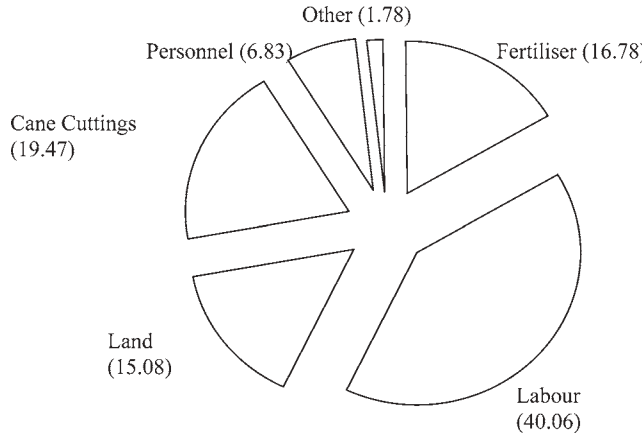

Figure 1 Relative costs of plantation inputs in the Java sugar industry 1897–1905[87]

A breakdown of the field costs of cane production during this period reveals five main areas of expenditure: supervision (by European and 'native' staff), land-rental, labour, fertiliser and cane-cuttings (*bibit*). Of these, labour involved in fieldwork, from the start of land preparation up to but not including the harvest (cane cutting and haulage was invariably booked to manufacturing rather than plantation costs), was by far the largest single expenditure, generally amounting to well over 50 per cent of plantation costs. The smallest expenditure in the agricultural sector of production – again almost invariably – was land rental, which often amounted to less than 15 per cent of total costs. This reflected both the industry's relative success in depressing the price of rentals (a success that it was subsequently unable to sustain) and the fact that the Java industry, even by that date, got a lot out of little as far as cane production was concerned. In between came the costs of supervisory personnel, fertiliser and, as we shall see, cane-cuttings or *bibit*. The exact cost of fertiliser inputs varied considerably from factory to factory, very much in line with application rates. At many factories, however, fertiliser ranked second only to labour among the major expenditures in the field.

87 Some 14 factories (out of a total of approximately 170 operating around 1900) have been used in Figure 1 to provide data from a geographical cross section of the industry and from a variety of sugar companies. The data makes no pretence to 'statistical validity', for which sufficient information is simply not available. In the list that follows, the names of the factories/their owners (or financiers)/the years covered are followed by the location of the data. 'KIT' means that copies of the factory or company reports concerned are located in the Library of the Koninklijk Instituut voor de Tropen, Amsterdam. Most other sources are archival. Wonopringo/NHM/1899–1903 NA NHM 7947 and 3122 file 593; Modjo-Agung/NHM/ 1899–1902 NA NHM 7947 Bandjardawa/Javasche Cultuurmij/1901–05, Bagoe/Javasche Cultuurmij/ 1901–05, Perning/Javaschse Cultuurmij/1900–5, Pesantran/Javasche Cultuurmij/1900–05 *Javasche Cultuur Maatschappij. Verslag over de boekjaar*, 1901, KIT;Tjomal/Cultuurmij. Tjomal/ 1901–1905 D. van Hinloopen Labberton, 'Invloed van de suikerfabriek op hare omgeving', *Archief Suiker*, 16 (1908), Bijblads, pp. 820–42; Gending /Koloniale Bank/ 1897–1904 NA Archief Koloniale Bank 1144–5; Poerwodadi/NHM/ 1898–1904 NA NHM 7944; Soerawinangoen (aka Ploembon)/NHM/1897–1901 NA NHM 7946; Gemoe/ Mij. tot Exploitatie der Kendalsche Suikerfabrieken/ 1900–04, Tjipiring/ Mij. tot Exploitatie der Kendalsche Suikerfabrieken 1900–04, *Verslag van de N.V. Mij tot Exploitatie der Kendalsche Suikerfabrieken* (Batavia: Dorp and Co, 1905), KIT; Kalibagor/ *Mij. tot Exploitatie der Suikerfabriek Kalibagor* (Amsterdam: De Bussy, 1897), KIT; Poerwokerto/NV Vennootschap Suikerfabriek 'Poerwkerto/ 1895–1901 *Verslag der NV Vennootschap Suikerfabriek 'Poerwokerto'* (Amsterdam: De Bussy, 1895), KIT.

Fertiliser, moreover, was not the only 'manufactured' input into cane agriculture in turn-of-the-century Java. The other was cane-cuttings, which from the early 1890s onward had come to constitute a major item of plantation expenditure. Farmed cane-cuttings bought from hill country '*bibit tuinen*' and transported to lowland sugar plantations on a grand scale proved to be the industry's most satisfactory answer to the problems posed by cane disease. Dependent on the same industrial transport infrastructure of rail and tramways through which fertiliser itself was distributed (and processed sugar moved to Java's ports), the arrangement circumvented the problems caused by propagation of cane from existing lowland stock, a practice that was seemingly closely associated with the phenomena of *sereh*. By the early years of the twentieth century, *bibit* growing had become big business, carried on either by independent entrepreneurs or by the factory owners themselves. Either way, it represented an exogenous, 'manufactured' input into the plantation parallel to that of fertiliser – and a costly one at that. Again extrapolating from what we know of production costs at some 20 factories around the turn of the century, expenditure on *bibit* sometimes exceeded that of fertiliser. Adding together the cost of fertiliser and *bibit* suggests that by the beginning of the twentieth century, 'manufactured', exogenous inputs of this kind accounted for as much as one-third of the total costs incurred by the Java sugar industry in the agricultural sector of production. With variations (land rentals as a percentage of total plantation expenditure were rising during the first decade of the twentieth century) this pattern of expenditure endured to 1914, and beyond.

Conclusion

The unique approach to sugar cultivation that characterised late colonial Java needs to be understood as a type of industrial agriculture, which was experimental and even revolutionary in orientation, rather than trailing behind contemporaneous practices in the West. The Fertiliser Revolution provides an important case study of the way in which industrial thinking, technologies and sciences worked themselves out in colonial settings, and in the Netherlands Indies in particular. It focuses attention on both external influences as well as some indigenous precedents (or more correctly, Java-centric precedents) that provide balance to the motivation of what took place. Implicitly (although this is not a part of the main argument), it disputes the idea of colonies as being on the periphery of scientific and technical thinking.

From the perspective of economic history and labour history, developments in Java's colonial cane fields in the late nineteenth and early twentieth centuries highlight the symbiotic combination of manual labour and intensive fertiliser use. In so doing, it provides a useful corrective to an overemphasis on the extractive nature of the colonial economy of sugar. It shows the truly industrial nature of plantation production and underscores an argument that 'the plantation' was a fluid form of production, fully capable of sharing in the key attributes of modernity defined in terms of both the work process and the application of science to the expansion of production. Implicit in this context is an argument that ecological and climatic conditions in 'the tropics' did not necessarily stand in the way of the adoption of agricultural advances that paralleled those of more temperate regions. In short, the fertiliser revolution in late colonial Java has major implications for a broader understanding of tropical plantation agriculture and its relation to economic modernity.